Implementation of Digital Control System for Inlet Condenser Valve Position Control to Enhance the Reliability of Salak Geothermal Power Plant

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***Abstract*—During 2017-2019, the Inlet Condenser Valve positioning system of unit 2 at the Salak geothermal power plant incurred control system damage, leading to its failure to respond to set point commands from the DCS, necessitating manual operation via a chainblock. This prolonged startup recovery disruptions to over 10 hours on average, resulting in diminished EAF unit performance and decreased power plant reliability due to frequent trips. Therefore, a control system engineering overhaul was imperative, transitioning from analog to digital control for valve positioning. The new system, based on PC interface utilizing Nexus MPC software, retained PID algorithms. Data processing in Excel determined precise response times, with PID tuning empirically derived from open-loop responses and refined through field testing via a trial and error approach. Analysis revealed excellent digital control performance, with an opening response time of 16.5 seconds and 0.02% error. Consequently, digital control implementation increased unit reliability in EAF performance by 0.0029% per hour, with 1.6-hour faster recovery times, resulting in a financial gain of Rp 115,796,250. Furthermore, engineering of the inlet condenser valve control system successfully prevented force outage incidents twice in 2023, indicating enhanced equipment and power plant unit reliability.**

Keywords—Inlet Condenser Valve, Hydraulic Valve, Digital Control, PID, EAF, Control System

I. Introduction (*Heading 1*)

The main cooling system is one of the cycles in Geothermal Power Plants (PLTP) which has an important role in the efficiency of the generating unit, namely by making and maintaining vacuum in condenser equipment. The function of the condenser is to condense the steam used by the turbine player into water by direct contact spray of cooling water and steam so as to make the condition vacuum at a pressure of 0.10 – 0.15 barA. The vacuum value of the condenser is also influenced by the water level in the condenser which must be set at a certain level, which is about 60% to obtain a good vacuum value. Setting the water level on the condenser uses three hydraulic valves where two hydraulic valves are located on the outlet side of the condenser which functions to adjust the amount of water flow of the main cooling water pump and one hydraulic valve is located on the inlet side of the condenser which functions to regulate the amount of cooling water flow to the condenser to condense steam used to rotate the turbine. Failure to regulate the condenser water level can cause turbine trips or generating units to stop production, because as a safeguard from much greater damage due to the failure of the hydraulic valves in regulating the condenser water level [1]. Setting the condenser water level on the inlet side must be accurate considering the dimensions of the large 72-inch condenser valve inlet so that even the slightest opening will affect the condenser water level, with a hydraulic drive and PID control system will facilitate control from the position of the condenser valve inlet. The PI control system is a combination of proportional and integral control actions that form proportional control – integral (PI controller) and P and I controller elements as a whole have the advantage of fast response and reduce errors so that valve opening is obtained according to the desired set point (DCS command) [2].

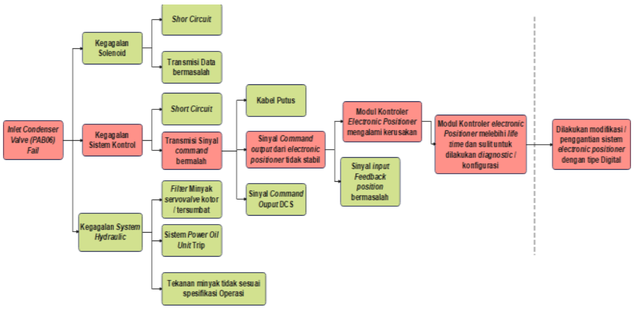
However, controlling the position of the condenser valve inlet with analog control often experiences damage and response time that is not as needed so that the condenser water level setting often also fails plus when the electronic positioner control is damaged which cannot respond to the command set point from DCS, opening the condenser valve inlet using a chainblock by pulling the mechanical valve manual. This will certainly make the plant start-up process take a long time and experience delays that make the performance of the EAF unit decrease and the difficulty of setting levels during normal operation which has great potential for force outage. This certainly indicates the non-running of the installed control system, where unit 1 and unit 2 use analog control systems that are very difficult to repair and have many weaknesses. By utilizing digital technology in the control system that has many advantages can be an effective solution, where the digital control system on the hydraulic valve equipment can respond to signals faster and can minimize noise and is easy to implement so that it will make it easier for operators when operating the unit

The problem of control system engineering is analysis and engineering, analysis is to investigate the properties of an existing system, while engineering is the selection and preparation of system components that carry out certain functions / tasks called performance specifications [3]. In addition to engineering / modification, analysis must also be carried out so that the function of the control system for valve positioning can be implemented with good performance. So that in engineering the control system in the inlet condenser valve will be compensated from analog control to PC-based digital control without changing the main system of the valve.

II. Research Methods

A. Problem Analysis

To start analyzing the problems that occur, field observations are carried out to help find the root of the problem and its solution, observations were carried out at Unit 2 of the Mount Salak PLTP by looking at the condition of the condenser valve inlet and interviews with plant operators. From the results of field observations, it was identified that the problems that occurred were damage to the position setting of the condenser valve inlet was that it could not prescribe the command set point from the DCS inputted by the operator which indicated that there was damage to the electronic positioner module which still uses analog controls and analog component components. By doing root cause problem solving, the root problem is obtained electronic positioner is unable to send command signals to the servovalve to open or close the condenser valve inlet. Seen in Fig 1 also specified a solution to solve the root cause of the damage to the electronic positioner module by compensating components of the module to PC-based didigtal control.



Gbr 1. Root Cause Problem Solving (RCPS)

Damage to the electronic positioner controller module is caused by a lifetime that has exceeded the limit but the spare parts are no longer available on the market and also to repair it encounters problems because spare parts are difficult to find and components of the analog card controller electronic positioner are obsolete. In addition, to perform diagnostics and configuration is also difficult because the system used is still analog. With the existing analog control system, the performance of the valve position movement control system is less than optimal when given a command signal using DCS from the control room. Delivered. The concept of valve positioning can be explained from the following block diagram

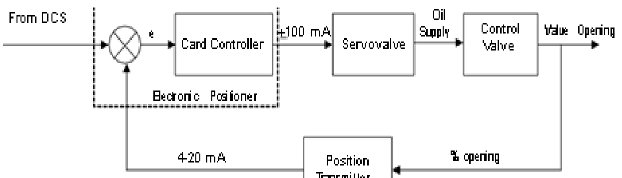


Fig 2. Valve Positioning Block Diagram

B. *Digital Control Design*

Designing a control system to replace the old control system requires a flowchart to obtain good results, here is a flowchart for digital control design at the condenser valve inlet.

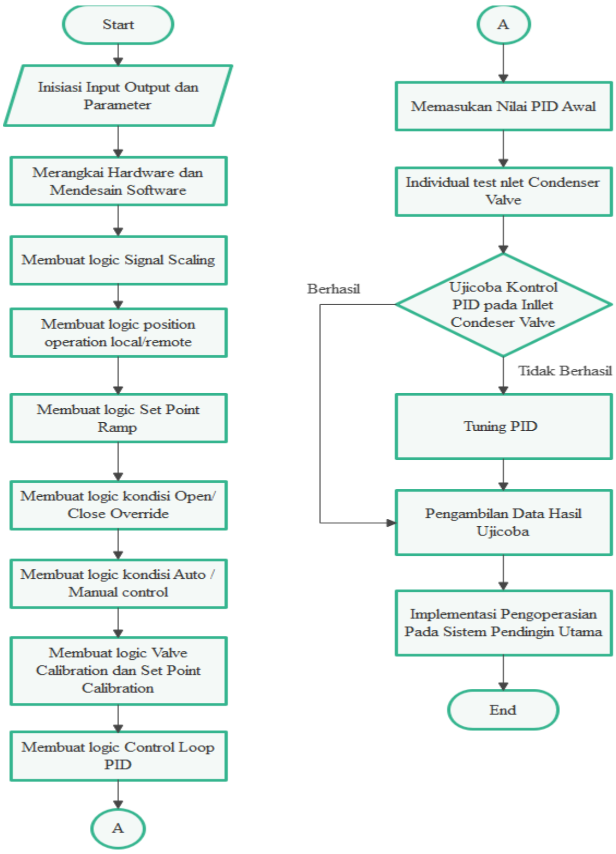


Fig 3 Digital Control Design Flowchart

The digital control used still uses the PID algorithm so that the valve position adjustment will have an accurate response and facilitate configuration for condenser level adjustment purposes.

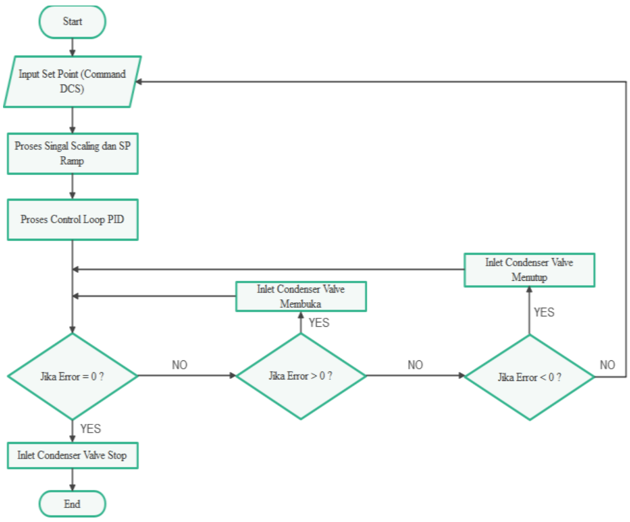


Fig 4. PID Control Flowchart Valve Positioning

From this PID fowchat, it can be seen that calculations will be carried out to produce an error value that is close to the set point, then an output signal is sent to the servovalve to regulate the flow of hydraulic fluid to the condenser valve inlet, the valve opening results will be read by the position transmitter sensor for recalculation so that an error value = 0 is obtained. In general the design of digital controls for electronic positioners

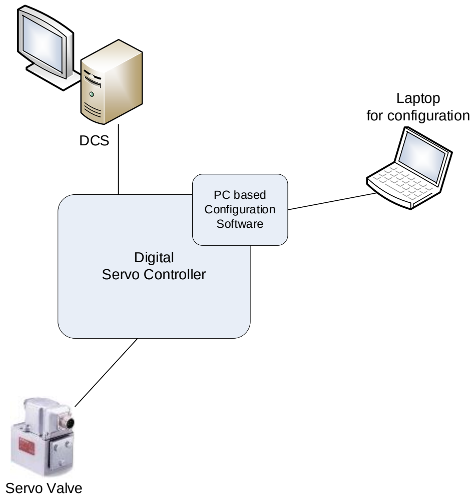


Fig 5. Digital Position Control System Block

With a PC Based interface, it will facilitate the configuration process of the equipment or constituent components in controlling the position of the valve, and to test and calibrate the valve process will also be easier. There are three communications, namely from the main DCS which will provide input as a set point to the electronic positioner then connected to a PC for input in configuring and the output is a signal to the servo valve to regulate the amount of fluid flow moving the valve. In this digital control, a redundant power supply system is also used to support the power needs of the elcetornic positioner so that it is more reliable, along with a wiring schematic from the digital control of the inlet condenser valve positioning

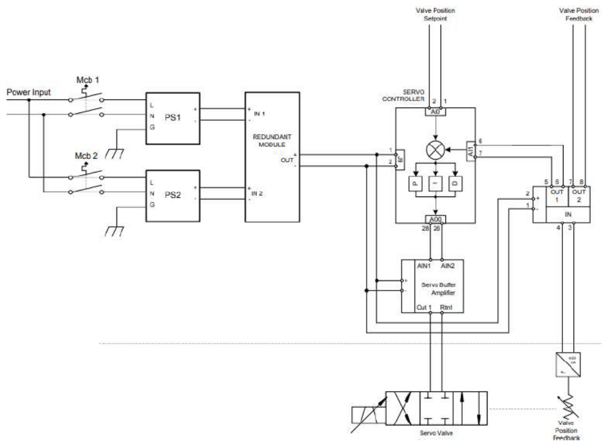


Fig 6. Schematics Control Digital Inlet Condenser Valve

The stability of the digital control system in the electronic positioner is better with two power supplies, where if one experiences a problem there will be no control reset on the valve position setting. This digital control concept no longer requires too many ADC and DAC equipment because it can be replaced with logic block functions in electronic positioning software.

C. Digital Control Implementation

The implementation process begins with the creation of logic and HMI for the condenser valve inlet. This logic will adjust the input and output signals so that they are as desired in the valve position setting. Making logic is divided into seven parts, the first logic made is logic signal scaling to make input in the range of 0-100%. Next, create a logic mode of operation between local or remote, then create logic SP Ramp to determine the time speed of the output signal. The logic made next is logic for protection of the system to make the inlet condensr valve force close and or force open, besides that logic is also made for the purposes of calibration of the valve and set point calibration. After the logic is made, then make the main logic for controlling valve position with the PID algorithm, here is the display of the main logic of the PID control loop

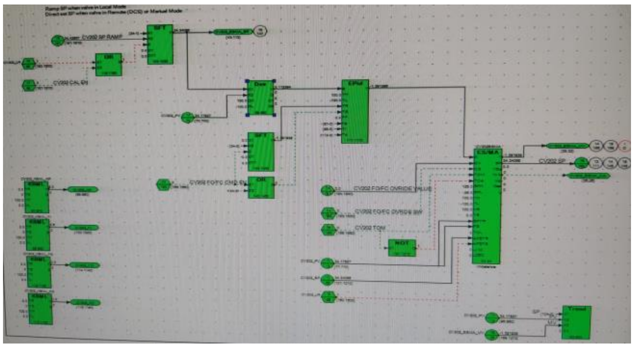


Fig 7. Logic Control Loop PID

PID control in this logic is contained in the EPid function block, this function block will set the PID constant with feed-forward / FF (feed-forward) and anti-integral saturation with the Laplace equation as follows:

In auto mode:

$$Y(s) = (K_p + \frac{1}{T_i * S} + \frac{K_d * T_d * S}{T_d * S + 1}) E(s) + FF(s)$$

In tracking mode:

$$Y(s) = TR(s)$$

In addition to the EPid function block, there is also an ES/MA function block which is a manual auto soft control for control loops with the function of limiting the amplitude and changes in output prices. With this function block, it is expected that there will be no high overshoot values and good steady state errors. The next implementation process is the creation of HMI (Human Machine Interface) which will make configuration easier, this HMI will be connected to the logic that has been made. Here's a look at the HMI Inlet Condenser Valve Position Control.

Fig 8. HMI display for configuration

III. Results and Discussion

In implementing PID into the control system, empirical PID tuning is carried out using the Ziegler Nichols meted which will later become the basic reference and comparison of PID values in the condenser valve inlet position control. Tuning is carried out in the open loop response with a maximum overshoot requirement of 0%, settling time of 15 seconds

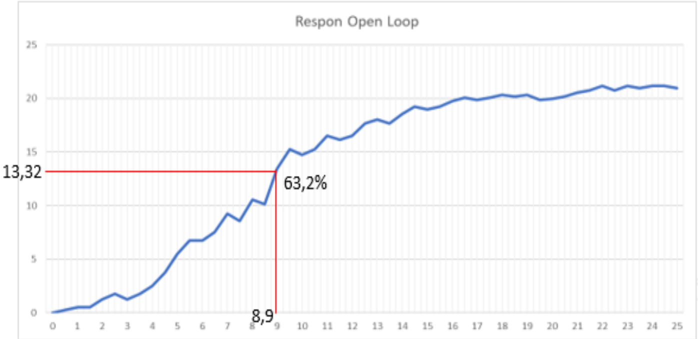


Fig 9. Graph of Open Loop Response Inlet Condenser Valve

From the open loop response graph, we will find the switching function of the valve opening system with the first-order system where the equation is

$$C(s) = R(s)\ \frac{k}{(s+a)} = \frac{k}{s(s+a)}$$

The system above if given input 1/s will become k / s (s + a), with this equation it can be found the response time equation of the results of inverse laplace

C(t) = 1 – e-at if t = 1/a will obtain an intial slope of

so that $e^{-at}|t_{=1/a} = e^{-1} = 0{,}367$

c(t) = 1 – 0.367 = 0.632 = 63.2% of output

The output value of the open loop graph is 21.15 then the slope value = 63.2% x 21.5 = 13.32. Furthermore, it can be known the time from the current chart of 13.32%, which is 8.9 seconds

$$\tau = 8{,}9\ detik, karena\ a\ \frac{1}{\tau}\ maka\ dapat\ dicari\ nilai\ a$$

$$a = \frac{1}{\tau} = \frac{1}{8{,}9} = 0{,}112$$

then look for the value of k,

k = ss x a = 21,15 x 0,112 = 2,36 until

$$C(s) = \frac{2{,}36}{s + 0{,}112}$$

Because it is given a step signal input of 20%, the switching function becomes

$$C(s) = \frac{2{,}36}{s + 0{,}112}\ x\ \frac{1}{20}$$

$$C(s) = \frac{2{,}36}{20s + 2{,}24} = \frac{0{,}118}{s + 0{,}112}$$

After obtaining the switch function, by looking at the open loop response graph on Gbr11 which is a reaction curve so that PID tuning can be done using Ziegler Nichols, the first method for two control models, namely PI and PID which results as follows

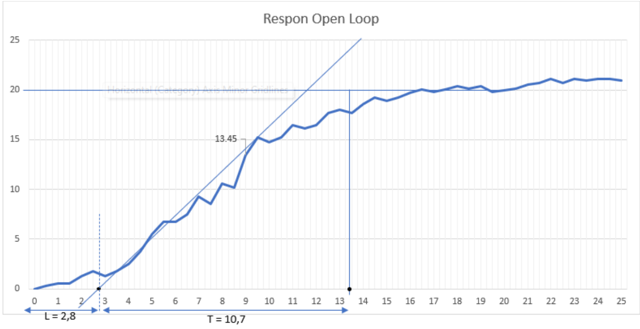


Fig 10. PID tuning with reaction curves

With known T = 10.7 and L = 2.8 then,

➔ For PI control obtained

$$Kp = 0{,}9\ \frac{T}{L} = = 3.440{,}9\ \frac{10{,}7}{2{,}8}$$

$$Ti = = 9.3 = \frac{L}{0{,}3}\frac{2{,}8}{0{,}3}$$

➔ For PID control obtained

$$Kp = 1{,}2\ \frac{T}{L} = = 4.581{,}2\ \frac{10{,}7}{2{,}8}$$

$$Ti = 2\ L = 2\ .\ 2{,}8 = 5{,}6$$

$$Td = 0{,}5\ L == 1.40{,}5\ .\ 2{,}8$$

After obtaining the value of constants from Kp, Ti and Td empirically with a switching function that has also been obtained from the calculation of the grastic response of the open loop Inlet Condenser Valve, then a step signal test was carried out with simulation using octave software to determine the system response with the PID constant empirically

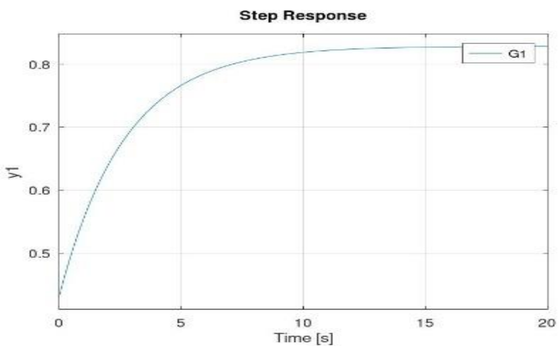


Fig 11. Step Response Results of PID Control in Octave

Based on octave simulations, the graph of the response step shows that the output value is still below set point 1, for that it is necessary to tune the PID constant directly in the field, namely by the try and error method. The first step in tuning is to increase the value of Kp and shrink the value of Ti and Td, along with the results of tuning the inlet condenser valve.

A. Tests with Kp 25, Ti 0, Td 0

Reducing the addition of the Kp value to 25, it is expected that the output value of the valve movement will reach the given set point, which is open 20%. The test results are shown in the graph below the value of the control signal starting to respond at 2.5 seconds and reaching the set point at 15 seconds. For the valve opening value or valve position starts moving at the 3rd second and reaches the set point at the 24th second, but the valve opening value slightly jumps above the set point and when the steady state there is an error of 0.13%.

At the 28th second, the valve opening value begins to fall close to the set point, so the steady state error becomes 0.02%

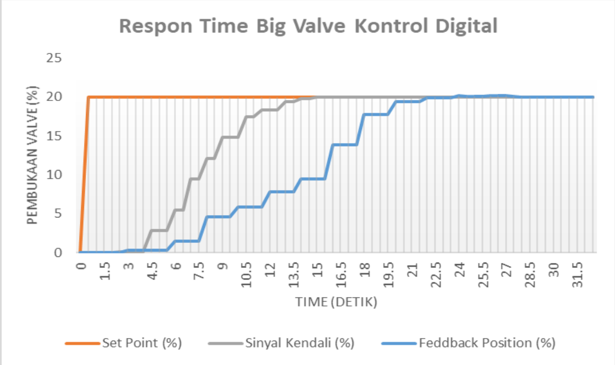


Fig 12. First Tuning Valve Movement Trend

Looking at the first test, the response time produced is still more than 20 seconds, then a second fine tuning will be done. If the first Kp value is enlarged to reach the set point and has a large enough error, the second fine tuning will be given a value of 25 < Kp > 4.58 to obtain a better value. And looking at the first fine tuning time response of 28 seconds so that the valve position change value is faster given nilia Ti = 6 according to the tuning data.

B. Tests with Kp 14, Ti 6, Td 0

In this second test, the same set point value of 20% is given and a graph is obtained as below

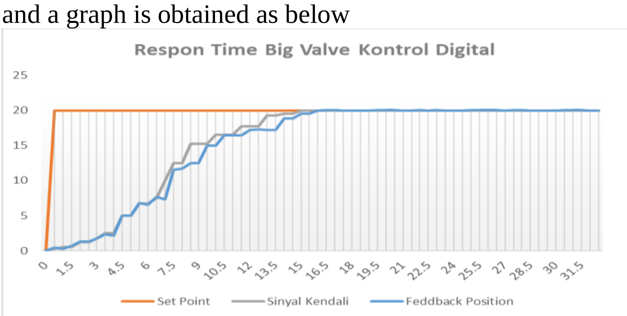


Fig 13. Second Tuning Valve Movement Trend

The control signal starts moving at 0.5 seconds after the set point is entered and reaches the desired value at 15 seconds. The valve opening also immediately moves following the control signal issued but the value is different, the valve position value reaches steady state at 16.5 seconds with a steady state error value of 0.02% without any jump in valve opening position to the set point. This means that the PID value setting in the digital electronic positioner inlet condenser valve control system has been successfully obtained, then this control system can be implemented to operate the inlet condenser valve from DCS for the purposes of starting up the unit or regulating vacuum during normal operation.

C. Work Analysis

After obtaining the right PID constant value then an experiment was carried out to open the condenser valve inlet to 100% then close back to 0%, Fig xx shows the trend of opening the condenser valve inlet where to open or adjust the position of the valve movement takes 16 seconds. The time of the control signal to reach this set point is set or limited by the logic signal set point ramp with the RatLmt function block which has the function of limiting the rate of change of the input signal, the logic SP ramp is set when the controller detects changes in set points then the value will increase to the desired set point within 15 seconds.

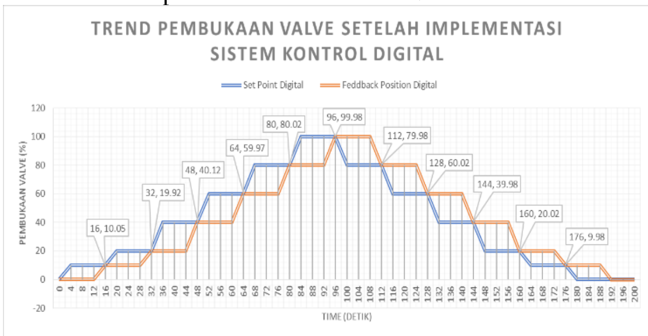


Fig 14. Open and Close Movement Trend

From the results of fine tuning, information can be obtained that the best practice of determining the PID constant is a try and error method where empirically the value obtained is far from ideal, but an empirical approach can facilitate the tuning process because there are parameters that become references. The best fine tuning step is to give the Kp value first without Ti and Td until the output is obtained according to the set point without any enlarged oscillations. After getting a new Kp value, add the Ti value so that the output changes are not too wild, and if there is still an overshoot, add the Td value. In this nexus controller, which has a PC user interface for overshoot cases, in addition to adding Td values, ES/MA logic block functions can also be added which is a soft manual auto control to limit the amplitude and changes in output prices.

D. Unit Reliability Analysis

With the increase in the performance of the control system of the plant equipment, the reliability of the plant will also increase, which of course the process of setting levels and vacuum ups will be faster. When the start-up process is faster, it will affect the increase in unit EAF performance, where EAF is measured based on time and production, so every one hour faster EAF electricity production will increase by 0.0018%. As an illustration, the condenser water level setting is maintained at a height value of 60% and at start up this level setting must be done manually by the operator in accordance with the procedure in the plant operation manual. Because the level value always fluctuates up or down during initial settings, the operator will be easier and faster when the condenser valve inlet can be opened from DCS with a faster response time than having to open using a chainblock. Or when the generating unit is normally operating, if there is a condenser level disturbance, to be able to keep the generating unit from force outage, it is necessary to adjust the opening of the condenser valve inlet, because it can be operated from DCS, the chances of successfully maintaining the level are greater. This is proven in 2023 where there is a condenser level disturbance in unit 2 which can then be resolved by the operator so that the unit does not force outage, along with the trend of setting the level when there is a disturbance and the unit does not force outage because it is easy for the operator to adjust the level by operating the condenser valve inlet from DCS.

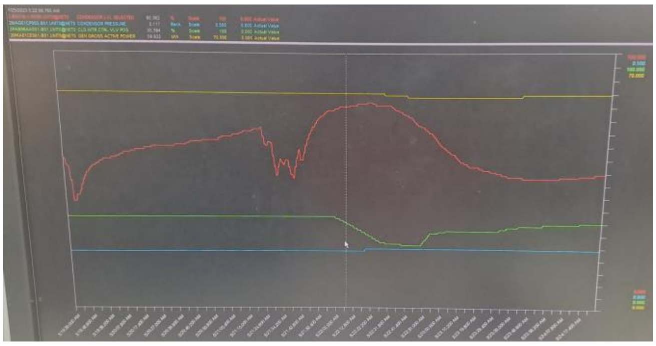


Fig 15. Level Setting Trend Through Inlet Condenser Valve

E. Economic Analysis

From the start-up report of unit 2 of the Gunung Salak PLTP in 2022 – 2023, where the operation of the inlet condenser valve already uses a digital control system, it has a faster time than the previous year when using chain blocks.

Table 1. Start Up Time Before and After

Big Valve Using *Chain Block*		*Big Valve* normal dengan *hydraulic*	
Time	Process	Time	Process
1.55 hours	Making a Condenser Vacuum	0.92 hours	Making a Condenser Vacuum
1.55 hours	Unit Load Normalization	0.58 hours	Unit Load Normalization
Duration = 3.1 hours		Duration = 1.5 hours	

So the savings obtained are:

a) Acceleration of disruption recovery
= *Duration of Big Valve* with *chain block* – Duration of *Big Valve* with *hydraulic*
= 3,1 Jam – 1,5 Jam
= 1.6 hours
So the time for start up to normal load will be faster by 1.6 hours

b) *Preventable Loss Opportunity*
Daya Mampu Netto (DMN) Unit 2 = 56.5 MW
Normal load acceleration = 1.6 hours
Loss Opportunity = DMN x Acceleration
= 56500 kw x 1,6 hours
= 90,400 kWH

c) Cost Savings or *Financial Benefits*
Spare part purchase cost = *IDR 193,371,750.00*
Number of start-ups 2022 = 3 times
Electricity Selling Price 2022 = Rp 1.140,- / kWH
Costs that can be saved = Selling price of electricity x *Loss Opportunity* x jumlah start up
= Rp 1.140,- / kWH x 90.400 kWH x 3
= Rp 309.168.000,00
Financial Gain = Savings – purchase costs
= IDR 309,168,000.00 - IDR 193,371,750.00
= Rp 115.796.250,00

IV. Conclusion

After the application of digital control on the inlet condenser valve, it was found that the digital control system has good performance in adjusting the position of valve movement, compared to analog control systems, the use of digital control will facilitate configuration, maintenance and operation. The results obtained answer the problem of controlling the position of the condenser valve inlet so that it can be operated through DCS with a moving time response of only 16.5 seconds and there is only an error of 0.02%. That way the operation no longer uses chainblocks which will speed up the start up process in terms of level settings and vacuum ups.

In the process of implementing this digital control, it still uses the PID algorithm which determines the value of the constants Kp, Ti and Td is sought by two methods, namely empirically and try and error as fine tuning in the field. Based on the analysis of the work carried out, the best practice of tuning PID in the field is by try and error which starts with giving the Kp value first without Td and Ti which finally obtained PID control parameters with values Kp = 14, Ti = 6, and Td = 0 resulting in the best response. Empirical determination of PID values is quite helpful in obtaining reference values to be given so that it can speed up the tuning process.

Increased plant reliability by making it easier for operators to operate the condenser valve inlet can make the start up time 1.6 hours faster or equivalent to an EAF increase of 0.0029%. In addition, another impact obtained is able to avoid force outage due to condenser level problems because it is easy for the operator to open or close the condenser valve inlet in adjusting the condenser level. This resulted in the company's financial profit of IDR 115,796,250.00 from the prevention of loss opportunity start-up recovery disorders. The application of a digital control system makes the reliability of unit 2 of the Salak Geothermal Power Plant increase so as to avoid losses in electricity production sales.

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